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PLANT NUTRIENTS IN POTATO PROCESSING WASTE WATER USED FOR IRRIGATION[1/]

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INTRODUCTION

Food processing industries discharge large volumes of waste water that are generally characterized by high organic matter content, large amounts of suspended solids, and various inorganic constituents including nitrogen, phosphorus, and potassium (3, 4, 5, 6). Until recently, food processing waste water was discharged into streams or rivers, but governmental regulations now prohibit this. Food processors must either treat their waste water to meet established water quality standards before discharging it, or find an alternative waste water disposal method. Secondary treatment, although expensive, has been satisfactory in some cases, but tertiary treatment with removal of nitrogen and phosphorus may be required in the future. Energy requirements for secondary treatment are high, and plant nutrients usually contained in the waste water are a valuable resource. Irrigating cropped agricultural land requires little energy and some of the nutrients can be used by growing plants. Therefore, irrigating with food processing waste water may be a long-term solution to the waste water disposal problem.

This report gives the nitrogen, phosphorus, and potassium concentrations in potato processing waste water and the amounts of water and included nutrients applied to fields at five potato processing plants in Idaho.

METHODS AND MATERIALS

The study was conducted at five potato processing plants in southern Idaho where the waste water was used to irrigate cropped fields. Orchardgrass, tall fescue, reed canary grass, or mixtures of these species were grown on the fields and harvested for hay or grazed by livestock. Waste water was sampled at each potato processing plant at monthly intervals during most of three processing seasons. An automatic sampler, activated at 20-minute intervals for 24 hours, delivered water into a freezer where it was frozen in a plastic container for storage until analyzed in the laboratory (2). The waste water samples were analyzed for total N by a Kjeldahl procedure, for total P using persulfate oxidation (1), and for K by flame photometry. The potato processors used water meters or other devices to measure the water applied to the field.

RESULTS AND DISCUSSION

The nitrogen, phosphorus, and potassium concentrations in the waste water reported in Table 1 are the averages of all samples from each process-

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Table 1. Average nutrient concentrations in potato processing waste water, 1972-3-4.

Processing plant*	Nitrogen	Phosphorus	Potassium
	ppm		
F1	34	6.2	90
F2	51	8.9	145
F3	48	12.8	141
S1	101	21.4	195
S2	48	8.0	123

* F = flood irrigation, S = sprinkler irrigation

ing plant. The nitrogen is primarily organic, with less than 1 ppm nitrate-N. Phosphorus in the waste water averaged 32 percent ortho, 22 percent acid hydrolyzable, and 46 percent organic. Potassium is usually water soluble and not organically bound in plant materials or in the waste water. Organic nitrogen must be mineralized by soil microorganisms before it is available to plants and is, therefore, a slow-release fertilizer. The nitrogen in the potato waste water probably will be utilized less efficiently than inorganic fertilizer nitrogen because of the losses in the biological transformations. Other nitrogen losses in these land disposal systems may be unusually high in some cases because the N applied may sometimes greatly exceed the crop requirements. Denitrification, which is most rapid in wet anaerobic soils, may also decrease the amount of nitrogen in the soil. Under wet conditions, the starchy wastes provide the energy needed for denitrification of the nitrate-nitrogen released when the organic wastes decompose in the top 6 inches of soil. Denitrification also decreases the potential groundwater pollution from nitrate.

Tables 2 through 6 show monthly average waste water applications, and nitrogen, phosphorus, and potassium applied in the waste water to three flood-irrigated and two sprinkler-irrigated waste treatment fields. The time covered is the time the treatment fields have been used for waste water irrigation.

Waste water applied and nutrients included in the water varied widely from field to field and with time. Average annual water applications ranged from 63 to 193 inches per acre. Nitrogen in the water ranged from 700 to 1960 lbs per acre per year. The lowest rate of nitrogen applied is probably not much higher than a good grass crop will remove, but the highest rate is exceedingly high.

Phosphorus fertilization from the waste water ranged from 130 to 565 lbs P per acre per year. All of these applications greatly exceed crop requirements and P fertility will increase greatly under irrigation with these waste waters. Potassium also greatly exceeds the amount expected to be removed by the crop. Potassium will reach an equilibrium and much of the K will leach with the excess irrigation water.

A nitrogen balance calculated for processing plant F2 for one year showed that about 10 lbs leached, 300 lbs was used by the hay crop, and the remainder of the 1200 lbs nitrogen per acre applied in the waste water was divided between denitrification and organic matter not yet decomposed.

Table 2. Nutrients in waste water from potato processing, Plant F1.

Date	Water applied	Nitrogen	Phosphorus	Potassium
	in		lbs/A	
May 1973	5.1	51	9.6	142
June	5.0	37	9.7	77
July	4.9	31	5.5	84
August	4.1	22	3.5	59
September	5.5	25	3.2	63
October	6.4	44	10.8	108
November	18.4	144	27.3	297
January 1974	12.9	76	16.4	217
February	10.9	97	11.0	268
March	5.4	44	7.6	117
April	6.0	69	11.1	154
May	6.9	53	12.6	128
June	5.0	46	9.8	208
July	4.9	17	1.7	43
August	4.1	17	2.5	48
September	5.5	25	4.8	80
October	6.4	43	10.6	133
December	14.2	111	10.8	339
January 1975	18.3	186	39.6	635
February	10.1	52	14.6	157
TOTAL	160.0	1190	222.7	3357
Annual mean	96.0	714	133.6	2014

Table 3. Nutrients in waste water from potato processing, Plant F2.

Date	Water applied	Nitrogen	Phosphorus	Potassium
	in		lbs/A	
January 1973	14.2	174	27.1	377
February	9.4	170	29.0	454
March	7.1	94	14.7	261
April	12.6	192	31.3	468
May	10.2	98	17.7	257
June	11.4	125	21.5	373
July	2.4	22	4.3	76
October	5.1	58	10.8	180
November	8.3	112	11.6	235
December	12.6	147	27.7	368
January 1974	12.6	174	28.4	446
February	7.5	116	10.9	199
March	7.1	89	14.5	225
April	8.3	125	16.4	286
May	9.1	116	22.0	162
June	4.7	27	5.1	-
TOTAL	142.6	1839	293.0	4367
Annual mean	95.1	1225	195.3	2911

Table 4. Nutrients in waste water from potato processing, Plant F3.

Date	Water applied	Nitrogen	Phosphorus	Potassium
	in	lbs/A		
January 1973	2.7	36	6.4	64
February	1.2	18	3.4	34
March	14.6	160	43.4	408
April	0	0	0	0
May	22.5	215	40.8	408
June	19.3	156	28.8	436
July	39.8	315	90.1	900
August	28.2	224	63.9	639
September	19.2	265	68.6	671
October	24.5	248	57.6	563
November	18.2	210	126.2	570
December	14.5	177	35.2	437
January 1974	19.0	281	69.0	657
February	17.3	178	68.9	829
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
September	5.4	47	13.6	149
October	15.0	150	40.6	569
November	18.6	209	63.2	732
December	5.2	60	11.0	190

Table 6. Nutrients in waste water from potato processing, Plant S2.

Date	Water applied	Nitrogen	Phosphorus	Potassium
	in		lbs/A	
January 1973	7.5	90	15.0	214
February	1.2	16	2.3	34
March	9.2	101	13.4	297
April	7.2	91	13.4	109
May	9.4	121	11.4	290
June	8.1	81	15.1	263
July	6.2	74	14.7	220
August	10.3	106	19.0	321
September	8.3	99	17.2	242
October	11.3	119	23.0	360
November	8.7	104	17.7	318
December	9.5	120	16.1	292
January 1974	10.7	122	20.6	389
February	0	0	0	0
March	2.2	27	3.8	67
April	1.4	18	1.9	28
May	0.8	6	1.3	15
TOTAL	112.0	1296	205.9	3459
Annual mean	79.0	914	145.3	2442

The water table ranged between 4 and 2 feet below the soil surface in the summer, thereby enhancing denitrification. The low leaching loss indicates that denitrification effectively removed most of the excess nitrate-nitrogen. At other locations where the water table was much deeper, leaching losses may be greater. Most of the organic matter in the potato processing waste water is starchy material that will decompose rapidly in soil. At some locations a thin crust of undecomposed organic matter accumulated on the soil surface, but there is little reason to expect large accumulation of organic nitrogen in the soil. The rapid decrease in chemical oxygen demand (COD) in the soil water samples extracted from the soil profile indicates that neither organic nitrogen nor phosphorus moves very deep into the soil. COD reduction was virtually completed in 1 to 2 feet of soil (7).

Phosphorus accumulated in the surface 6 to 12 inches of soil. The added organic matter decomposed rapidly enough to provide adequate phosphorus and nitrogen for rapid grass growth. The hay contained high nitrogen levels and protein contents ranged from 15 to 20 percent. Nitrate contents in the forage were generally within acceptable limits, with most samples ranging from 400 to 2500 ppm NO_3^--N.

The market value of the nutrients applied in the waste water was calculated based on average local prices (Table 7). These values do not necessarily represent the value of the nutrients on the fields to which they were applied. Applications were much higher than would produce an economic return. To obtain better nutrient utilization, the water could be spread over more acres of land, irrigating at a rate that would fertilize the grass or other crop at a nearly optimum rate. This may or may not be a viable solution to the problem, depending on the availability of land that can be irrigated

Table 7. The value of nutrients from potato processing waste water used for irrigation.

Processing Plant	Average value, dollars per acre per year*			
	Nitrogen	Phosphorus	Potassium	Total
F1	193	83	290	566
F2	331	121	419	871
F3	530	350	866	1746
S1	392	111	394	897
S2	247	90	352	689

* Average fertilizer value: N = \$0.27/lb, P = \$0.62/lb, K = \$0.14/lb

without runoff, and the additional water distribution cost. Nevertheless, an effort should be made to get better nutrient utilization by irrigating additional land where the rates are excessive. Perhaps, when the amount of nutrients in the waste water is publicized, farmers will wish to use the waste water on their farms. Through this, or other means, the nutrients and water should be used more efficiently. After decreasing nutrient applications, growing higher value cash crops could also increase the return from the waste water.

Flood irrigation with the warm processing waste water warms the soil and allows infiltration throughout the year. The growing season may be lengthened several days by the warm water. Because a grass crop will grow throughout the growing season, it should remove more nutrients from the soil than row crops such as corn, potatoes, or sugarbeets. Sprinkling cools the water, allowing ice to accumulate over frozen soils during cold winter months.

In conclusion, irrigating cropped agricultural land with potato processing waste water is solving a difficult environmental problem, saving some of the nutrients and water that would be lost through conventional treatment processes, and saving a great deal of energy compared to that consumed in secondary treatment of liquid wastes. With good management, waste water irrigation systems work satisfactorily, but the waste water and its nutrient content could be used more efficiently by spreading the water over larger land areas and decreasing the nutrient applications to rates more nearly approaching those needed for efficient crop growth.

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